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# Knowledge fusion method of process contradiction units for process innovation

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**Abstract**

Process contradiction unit, which is the basic element of the process contradiction matrix, is one kind of process innovation knowledge. Process contradiction unit is composed of process contradiction properties and process inventive principles. Through the knowledge accumulation, which is based on bilayer social wiki network, a large number of knowledge units can be obtained. However, because of the complexity of process innovation, the knowledge units can't be used until them have been fused. In this case, how to fuse the discrete, rough knowledge into a single with all the wisdom of knowledge-contributors is the basic work of knowledge accumulation. A knowledge fusion method of process contradiction units by semantic extracting and semantic fusion is proposed in this paper. Finally, an illustrative example is used to demonstrate the applicability of the knowledge fusion method.

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*Keywords:* process innovation, process contradiction units, knowledge fusion, semantic extracting;

## 1. Introduction

Process innovation is a great change in production technology. The essence of the process innovation is the integrated use of knowledge, finding the technical contradictions and the resolving theories to solve the process problems. Reasonable and efficient knowledge accumulation is the prerequisite and basis for effective knowledge application in process innovation [1]. Process innovation knowledge (PIK) is a complicated knowledge that contains a large number of technical personnel's collective intelligence; it has the characteristics of wide range dispersion, fuzziness, strongly empirical, high correlation, and multidisciplinary fusion [2]. Social network technologies and wiki technologies can provide a knowledge sharing and accumulation platform through knowledge collaborative editing and collaborative control. Thereby, a PIK accumulation model based on bilayer social wiki network has been proposed [3, 4] as shown in Fig. 1. The accumulation of PIK is divided into three steps: knowledge contribution, knowledge fusion and knowledge refinement. The main content of this paper is to explore the knowledge fusion. After publishing


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the knowledge theme, knowledge-contributors accumulate their wisdom of process technique. It is knowledge fusion to merge rough, discrete knowledge units into one PIK unit with all the wisdom of knowledge-contributors.

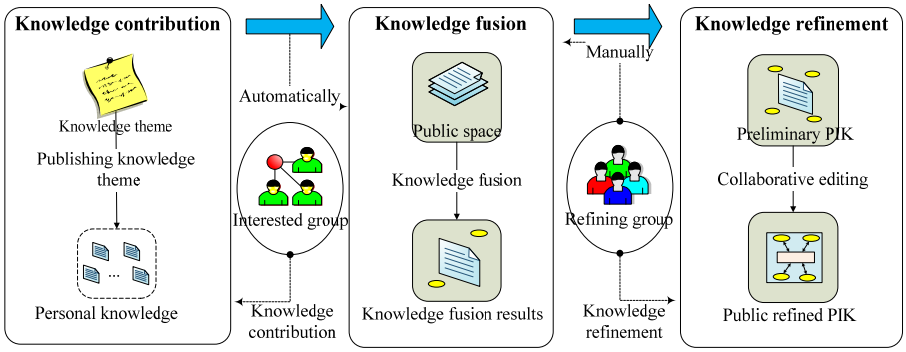



Fig. 1. Accumulation model of process innovation knowledge.

The process contradiction unit, which is a part of process contradiction matrix, is the description of process problem and the corresponding process inventive principles, has the form of natural language and engineering language. In the field of knowledge fusion, there are multiple semantic models and integration frameworks [5, 6]. However, different from the knowledge fusion method before, the fusion of process contradiction units has its own characteristics. First, because the compositions of process contradiction unit are not only terms but also sentences, the compatible knowledge fusion method is needed. Second, because process term is the language under the background of certain process problems, it is necessary to establish dedicated process term ontology. Third, because the relationships between the process terms are complex, it has to use the knowledge fusion mechanism to control the knowledge fusion process. In these cases, this paper puts forward a fusion method of process contradiction units under the mode of bilayer social wiki network.

## 2. The fusion framework of process contradiction units

Process innovation and product innovation constitute the enterprise technology innovation system [7]. Process innovation is a basic guarantee for the realization of product innovation, and is also a fundamental way for the sustainable development of manufacturing industry. However, the theory of TRIZ is aimed at product innovation, and suitable for solving problems in product design process. The theory lacks of the properties and methods orienting process field and solving process problems. The essence of process innovation is to find out technical contradictions in process problem, resolves these contradictions gradually based on the scientific principles, and creates new or improved manufacturing technology.

Process contradiction appears while trying to improve one desirable process property another desirable process property deteriorates. Conventional problem solving generally leads to a compromise solution. However, the most inventive solution is obtained when a process problem containing a contradiction is solved by completely eliminating the contradiction. As a result, this paper puts forward the concept of process contradiction matrix, which is made up of process contradiction units. Process contradiction unit, which is the unit of process contradiction matrix, is one kind of the PIK. Using for reference from the idea and method of classic TRIZ, which is used in the field of process innovation, a process contradiction unit ( $U$ ) is composed of process contradiction properties ( $P$ ) and the corresponding process inventive principles ( $C$ ). The mathematical methods is used to indicate the process contradiction unit, which is a pair

$$U = \{P, C\}; P = \langle p \to \overline{p} \rangle .$$

Where $p$ represents the contradiction property that want to improve, $\overline{p}$ represents the contradiction property that may deteriorate when $p$ is improved. The main function of process contradiction unit is solving specific process problems of certain process areas.

Knowledge fusion of PIK is one of the key technologies for process innovation. Knowledge fusion is different from the information integration, the essence of knowledge fusion is to transform discrete, relevant knowledge units into a knowledge unit with all the wisdom of knowledge-contributors, which we called PIK unit in process innovation. Through the contribution of process contradiction units, a large number of rough knowledge units can be obtained basing on bilayer social wiki network [3]. However, in the process of solving a certain process problem, the descriptions of process contradiction units are different from knowledge-contributors. Among these descriptions, some have the same meaning, some have the different meanings, some descriptions are contained in the others etc. In order to solve this problem, this paper proposes a knowledge fusion method by using semantics extracting and semantic fusion. The fusion mode of process contradiction units is proposed as shown in Fig. 2.

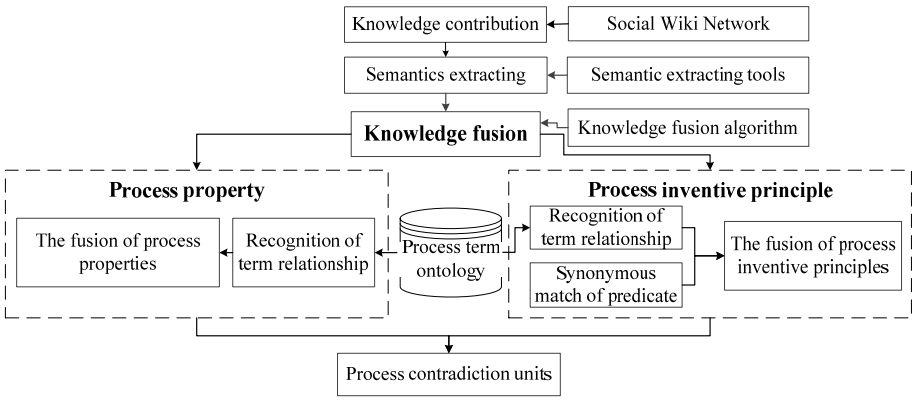



Fig. 2. The fusion framework of process contradiction units.

## 3. The fusion of process properties

Process property is the process characteristic that affects the product manufacturing process in the respects of design, material, cost, method and machine tool [8]. Process property is described in the form of terms, and has the characteristic of ontology. This paper uses semantic recognition of process terms and process term ontology to extract the process properties.

Process term ontology is a data structure [9]. Thus, the process term ontology is a set of definition, classes, relation, functions and other objects of speech [10, 11]. The mathematical methods is used to build the process term ontology, which is a pair

$O = (T, R)$

Where $T$ is a set of nodes (representing process terms), some of which are relations. $R$ is a set of restrictions, of the form of $\langle t_i \rightarrow t_j \rangle$ between the process terms $t_i$ and $t_j$. $t$ is used to refer to each process term of set $T$, while a arrow separates process term in the restrictions. The restrictions are not limited to have two members besides the relation. Therefore, an ontology is a hyper-graph with $T$ the set of nodes and $R$ the set of hyper-relations (which we call restrictions). For clarity, in this paper the process term ontology is represented as graph, where nodes are process terms and edges are restrictions. The process term ontology of welding is shown in Fig. 3, and the relations of process term ontology are shown in Table 1.

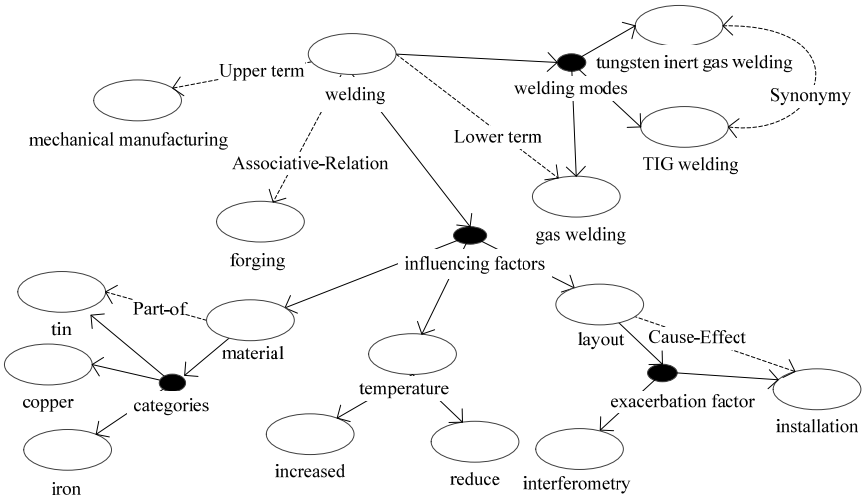



Fig. 3. The process term ontology of welding.

Table 1. The relation of process term ontology.

| Term ontology relation | Definition | Examples |
|---|---|---|
| Synonymy | The terms that have different form to express the same meaning. | *water*=*$H_2O$* ; *electric spark machining*=*EDM* |
| Kind-of | Belongingness between terms | The upper term of *welding* is *machining*; the lower term of *metal* is *steel*. |
| Associative-Relation | The terms that have same upper term | The relation between *Water* and *oil* is associative-relation, because they have the same upper term *liquid*. |
| Part-of | One is part of the other. | *Hammer head* and *hammer handle* are parts of hammer. |
| Cause-Effect | One leads to the other. | *Welding* leads to *deformation*. |

The mechanism of term fusion is shown as follow.

- $t_i \subset t_j$ , $t = t_j$ ;
- $t_i \supset t_j$ , $t = t_i$ ;
- $t_i = t_j$ or unable to determine the relation between terms, $t$ chooses the term who has the largest number of occurrences.

## 4. The fusion of process inventive principles

Process inventive principle is the resolving principle, which summarized from process problem resolving principle of certain process problems. This paper puts forward the method combined with semantics extracting and semantic fusion merging multiple process inventive principles into a single. In order to describe the fusion process of process inventive principles, we give the following definitions: $C$ is a process inventive principle, $L$ is the description of the process inventive principle, $T=\{t_1,t_2,...,t_m\}$ is terms set (containing subject, object and parameters), $P=\{p_1,p_2,...,p_n\}$ is the predicates set. Then, the hierarchical structure of process inventive principles $C$ can be expressed as:

$$C \ \Gamma \ L \ ; \quad L_i \ \square \bigcup (t_i) \oplus \bigcup (p_j) \quad (i=1,2,...,n; j=1,2,...,m)$$

Where $\Gamma$ means 'represented by'; $\square$ means 'denoted'; $\oplus$ is the symbol for term fusion.

The process of knowledge fusion is as follows:

a) Apply deep syntactic analysis to process inventive principle, using NLPWin (Natural Language Processing of Windows) linguistic tool [12, 13] to extract logical form triples (subject-predicate-object).
b) Through semantic mapping, translate the logical form triples into the form of SVPO (subject- verb-parameter - object). The semantic mapping of subject, predicate and object is easy, needn't to explain. Parameter is the term with measuring meaning or supplement meaning, such as size, area, pattern, mode, principle etc. For example, process inventive principle: *Fan reduces the temperature of the components*. Through syntactic analysis and semantics extracting, the sentence breaks up into: *fan* (subject) *reduces* (verb) *components* (object) *temperature* (parameter).
c) Through knowledge fusing of process term, multiple statements are merged into one semantic graph. The nodes in the graphs correspond to process terms and the link between them corresponds to predicate (verb). For the fusion of predicate (verb), the synonymous matching method is used. For example, the verb *alter*, *alternate*, *convert*, *vary* have the same meaning as *change*. Hence, the synonymous matching result of *change* and *vary* is *change*.
d) Convert the semantic graph into natural language.
e) Through the knowledge refinement, refine the process inventive principle of certain form from the natural language.

## 5. An illustrative example

This paper takes the knowledge fusion process of a welding problem for example, to elaborate the knowledge fusion of process contradiction units. ***Process problem***: *welding defects of the circuit board appeared frequently in the welding process, such as open solder, empty solder and inveracious soldering.* The welding enterprise wants to accumulate the wisdom of technical staff using the PIK accumulation platform. Through knowledge accumulation, it can fuse the wisdom into one process contradiction units. The knowledge fusion steps are as follows:

**Step1:** Pre-fusion preparation of process contradiction units, including process problem publishing and knowledge contribution.

**Step2:** Knowledge fusion of ***process contradiction properties***. Through knowledge contribution, three pairs of process contradiction properties have been acquired.

$P_1 = \langle \text{welding defects} \rightarrow \text{welding position} \rangle$;

$P_2 = \langle \text{welding quality} \rightarrow \text{welding position} \rangle$;

$P_3 = \langle \text{welding defects} \rightarrow \text{the space layout of weldment} \rangle$.

Through analyzing the process contradiction properties by process term ontology, we can find $\langle \text{the space layout of weldment} \subset \text{welding position} \rangle$, thus *welding position* is selected. Since $\langle \text{welding defects} = \text{welding quality} \rangle$, and $f_{\text{welding defects}} \succ f_{\text{welding quality}}$, we can choose *welding defects* as knowledge fusion result of process contradiction properties. After the knowledge fusion, the technical contradiction is: $P = \langle \text{welding defects} \rightarrow \text{welding position} \rangle$. Because the three process contradiction properties have the similar meaning, the corresponding process inventive principles can do knowledge fusion.

**Step3:** Knowledge fusion of ***process inventive principles***. Corresponding to process contradiction properties, there are three process inventive principles: $C_1$ =*Infrared heating can control welding temperature before welding;* $C_2$ =*Filling nitrogen can prevent oxidation before welding;* $C_3$ = *Non-contact welding can reduce bridging and solder balls.* By semantic analyzing, $C_1$ and $C_2$ have the similar meaning, can fused into one process inventive principles.

First, extract process terms from the process inventive principles above by semantic extracting tools. The semantic hierarchical structure of process inventive principles is obtained as shown in Fig. 4:

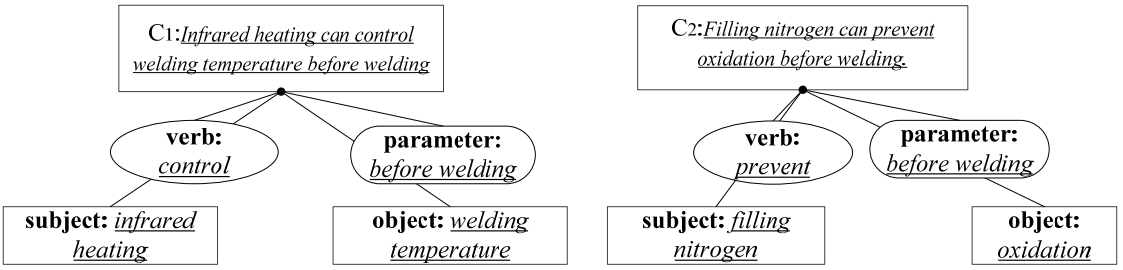



Fig. 4. The semantic hierarchical structure of process inventive principles.

Second, fuse the process terms into a semantic graph as shown in Fig. 5.

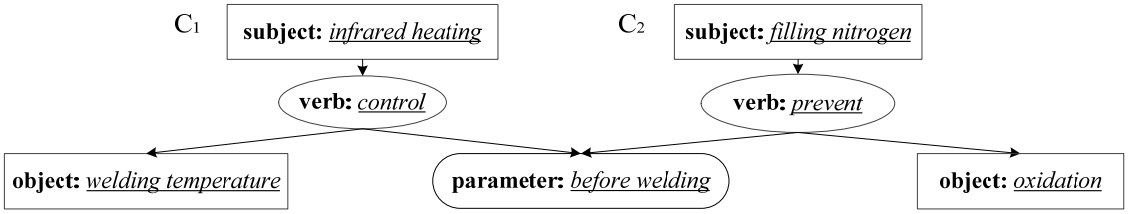
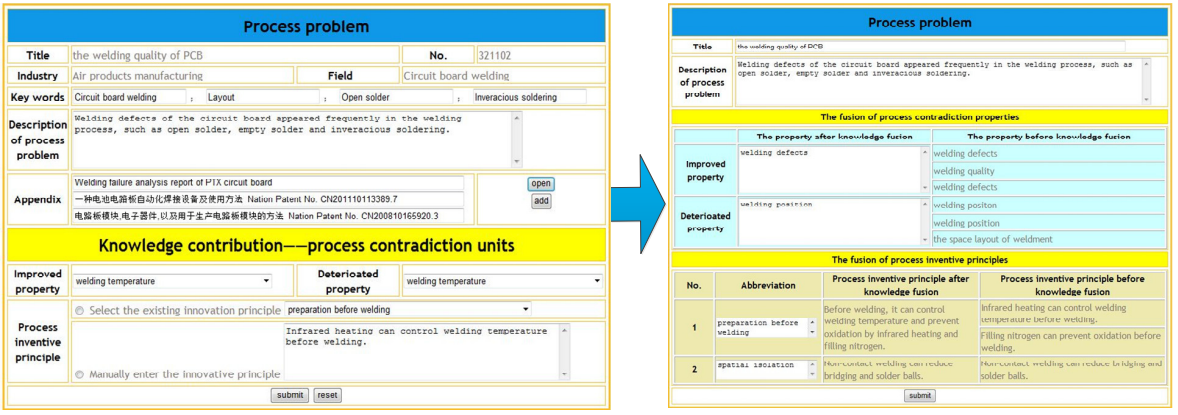



Fig. 5. The semantic graph of process inventive principles.

Third, the process inventive principle is acquired: *Before welding, it can control welding temperature and prevent oxidation by infrared heating and filling nitrogen.*

Finally, through summarizing from the process inventive principle has been fused, we can acquired the process inventive principle of abbreviation form: *preparation before welding* (the knowledge fusion result of $C_1$ and $C_2$) and *spatial isolation* (knowledge fusion result of $C_3$). Fig. 6 shows the knowledge contribution and knowledge fusion interface of the PIK accumulation system based bilayer social wiki network.




A. Knowledge contribution of process contradiction units

B. Knowledge fusion of process contradiction units

Fig.6. Knowledge contribution and knowledge fusion interface of the PIK accumulation system.

## 6. Conclusion

The main effort of this article is to explore the knowledge fusion method of process contradiction units. Through establishing the mode of knowledge fusion, we use semantic extracting and semantic fusion to fuse the discrete, rough process contradiction unit into a single with all the wisdom of knowledge-contributors.

From the results we obtained, the implications are elaborated in the following aspects:

- The process term ontology is proposed to solve the problem of process term fusion.
- By using semantic extracting, it can change the natural language into logical form triples. Through semantic mapping, it can obtain the semantic construction of SVPO finally.
- The term fusion mechanism is proposed in this paper. However, the relations among process terms are very complicated, in order to improve the quality of knowledge fusion, we should do some research on the relations of process terms in the future work.

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